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US-PAT-NO: 6461494

DOCUMENT-IDENTIFIER: US 6461494 B1
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TITLE: Methods for plating semiconductor workpieces using a workpiece-engaging electrode assembly with sealing boot

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US Patent No. - PN (1):
6461494

(12) **United States Patent**
Batz, Jr. et al.

(10) **Patent No.: US 6,461,494 B1**
(45) **Date of Patent: Oct. 8, 2002**

(54) **METHODS FOR PLATING SEMICONDUCTOR WORKPIECES USING A WORKPIECE-ENGAGING ELECTRODE ASSEMBLY WITH SEALING BOOT**

(75) Inventors: **Robert W. Batz, Jr.**; **Kenneth C. Haugan**; **Harry J. Geyer**; **Robert W. Berner**, all of Kalispell, MT (US)

(73) Assignee: **Semitool, Inc.**, Kalispell, MT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/390,091**

(22) Filed: **Sep. 3, 1999**

Related U.S. Application Data

(63) Continuation of application No. 08/940,685, filed on Sep. 30, 1997, now Pat. No. 6,001,234.

(51) **Int. Cl.**[7] **C25D 7/12**; C25D 17/06

(52) **U.S. Cl.** **205/123**; 204/297.08; 205/143; 205/157

(58) **Field of Search** ..... 205/123, 143, 205/157, 291, 640, 668, 118; 204/224 R, 285, 287, 297.01, 297.06, 297.08

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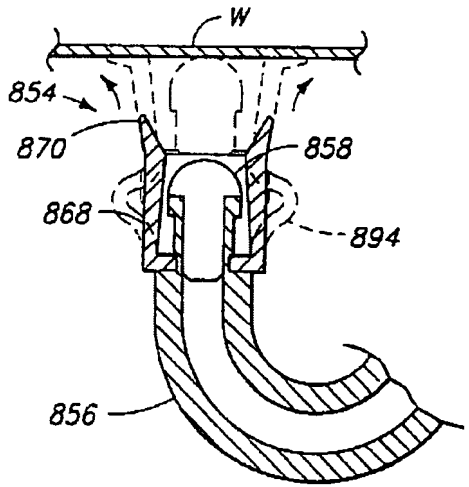
(57) **ABSTRACT**

Methods used in semiconductor electroplating systems, such as for plating copper, onto a semiconductor wafer or other semiconductor workpiece. The methods apply to patterned metal layers plated onto seed layer which is partially protected by an overlying photoresist or other coating. The methods employ an electrode assembly which has a boot which seals about a contact face of the electrode. The sealing is performed by engaging the seal against photoresist to prevent corrosion of the seal layer. The area enclosed by the sealing includes a via which is surrounded by the seal. The electrode contact extends through the via to provide electrical contact with the metallic seed layer. Plating of copper or other metal proceeds at exposed seed layer areas.

5 Claims, 38 Drawing Sheets



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electroplating to occur upon exposed seed layer areas of the processed surface. Such exposed seed layer areas may be trenches, vias or other features where the photoresist layer **564** is not present to cover the seed layer **562**. The electrical current causes electroplating to occur on such exposed seed layer areas.

Still further, the methods preferably include excluding plating, or other processing liquid from the sealed space to substantially reduce or eliminate plating or other action in the area immediate adjacent to the contact with the electrode.

The methods described above are of particular relevance to plating copper onto semiconductors.

Plating Bowl Assembly

FIG. **42** shows an electroplating bowl assembly **303**. The process bowl assembly consists of a process bowl or plating vessel **316** having an outer bowl side wall **617**, bowl bottom **319**, and bowl rim assembly **314**. The process bowl is preferably circular in horizontal cross-section and generally cylindrical in shape although other shapes of process bowl may be possible.

The invention further advantageously includes a cup assembly **320** which is disposed within process bowl vessel **316**. Cup assembly **320** includes a fluid cup portion **321** having a cup side **322** and a cup bottom **323**. As with the outer process bowl, the fluid cup **321** is preferably circular in horizontal cross-section and cylindrical in shape. The cup assembly also has a depending skirt **371** which extends below the cup bottom **323** and has flutes **372** open therethrough for fluid communication and release of any gas that might collect as the chamber below fills with liquid. The cup assembly can be made using upper and lower portions which couple together at a cup main joint **387**. The cup is preferably made from polypropylene or other suitable material, which is advantageously dielectric.

The lower opening in the cup bottom wall is connected to a riser tube **361** which is adjustable in height relative thereto by a threaded connection. The riser tube seals between the bottom wall **319** of the process bowl and the cup bottom **323**. The riser tube is preferably made from polypropylene or other suitable dielectric material. A fitting **362** connects the riser tube **361** and the fluid inlet line **325** to allow adjustment of the anode vertical position. The fitting **362** can accommodate height adjustment of both the riser tube and inlet line **325**. The inlet line is made from a conductive material, such as titanium and is used to conduct electrical current to the anode **324**, as well as supply fluid to the cup.

Process fluid is provided to the cup through fluid inlet line **325**. The fluid inlet line rises through riser tube **361** and bowl bottom opening **327** and through cup fluid inlet openings **324**. Plating fluid fills the cup portion **321** through opening **324** as supplied by a plating fluid pump (not shown) or other suitable supply which provides the fluid under at least some pressure for delivery.

The upper edge of the cup side wall **322** forms a weir which determines the level of plating liquid within the cup. Excess fluid pours over this top edge surface into the overflow chamber **345**. The fluid held in the overflow chamber **345** is sensed by two level detectors **351** and **352**. One level detector is used to sense a desired high level and the other is used to sense an overfull condition. The level of liquid is preferably maintained within a desired range for stability of operation. This can be done using several different outflow configurations. A preferred configuration is to sense the high level using detector **351** and then drain fluid through a drain line as controlled by a control valve. It is also possible to use a standpipe arrangement (not illustrate), and

such is used as a final overflow protection device in the preferred plating station **303**. More complex level controls are also possible.

The outflow liquid from chamber **345** is preferably returned to a suitable reservoir. The liquid can then be treated with additional plating chemicals or other constituents of the plating or other process liquid and used again.

The plating bowl assembly **303** further includes an anode **334**. In the preferred uses according to this invention, the anode is a consumable anode used in connection with the plating of copper or other metals onto semiconductor materials. The specific anode will vary depending upon the metal being plated and other specifics of the plating liquid being used. A number of different consumable anodes which are commercially available may be used as anode **334**.

FIG. **42** also shows a diffusion plate **375** provide above the anode **334** for rendering the fluid plating bath above the diffusion plate with less turbulence. Fluid passages are provided over all or a portion of the diffusion plate to allow fluid communication therethrough. The height of the diffusion place is adjustable using three diffuser height adjustment mechanisms **386** and secured by three mounting fasteners **389**.

Plating Anode Shield

The invention also includes an anode shield **393** which can be secured to the consumable anode **334** using anode shield fasteners **394**. The anode shield and anode shield fasteners are preferably made from a dielectric material, such as polyvinylidene fluoride or polypropylene. The anode shield is advantageously about 2–5 millimeters thick, more preferably about 3 millimeters thick.

The anode shield serves to electrically isolate and physically protect the back side of the anode. It also reduces the consumption of organic plating liquid additives consumed. Although the exact mechanism may not be known at this time, the anode shield is believed to prevent disruption of certain materials which develop over time on the back side of the anode. If the anode is left unshielded the organic chemical plating additives are consumed at a significantly greater rate. With the shield in place these additive are consumed less. The shield is preferably positioned on the anode so as to shield it from direct impingement by the incoming plating liquid.

The invention thus also include methods for plating which include other method steps described herein combination with shielding a consumable anode from direct flow of plating liquids using a dielectric anode shield.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

What is claimed is:

1. A method for electrochemically processing a wafer, comprising:

selecting a contact assembly having at least one electrical contact and a yieldable sealing member, said yieldable sealing member having a bellows wall structure;

engaging the surface of the wafer using the yieldable sealing member, said yieldable sealing member bearing against the surface of the wafer to form a barrier therewith that inhibits entry of processing fluid into a

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US-PAT-NO: 6461494

DOCUMENT-IDENTIFIER: US 6461494 B1
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TITLE: Methods for plating semiconductor workpieces using a workpiece-engaging electrode assembly with sealing boot

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6461494

sealed space forming a first region that includes the at least one electrical contact, the yieldable sealing member also defining a second region external to said yieldable sealing member;

contacting a contact point on the surface of the wafer with said electrical contact to form an electrically conductive connection between the contact assembly and said wafer, said contact point being disposed in the first region;

contacting the surface of the wafer corresponding to the second region with an electrolyte pursuant to electrochemical processing of the surface;

supplying electrical power through the electrical contact to the wafer to electrochemically process the portion of the wafer lying in the second region.

2. A method as claimed in claim 1 wherein said yieldable sealing member includes a rim portion for engaging the surface of the wafer and forming a barrier therebetween.

3. A method as claimed in claim 2 wherein when contacting said contact point the yieldable sealing member yieldably deforms for enabling the electrical contact to contact said contacting point.

4. A method as claimed in claim 3 wherein the rim portion of said yieldable sealing member splays outward when yieldably deforming.

5. A method as claimed in claim 1 wherein said electrochemical process includes an electroplating process.

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2	US 6001234 A	59		USPAT

US-PAT-NO: 6274013

DOCUMENT-IDENTIFIER: US 6274013 B1

TITLE: Electrode semiconductor workpiece holder

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US Patent No. - PN (1):
6274013

(12) **United States Patent**
Bleck et al.

(10) **Patent No.: US 6,274,013 B1**
(45) **Date of Patent: *Aug. 14, 2001**

(54) **ELECTRODE SEMICONDUCTOR WORKPIECE HOLDER**

(75) Inventors: **Martin Bleck; Kenneth C. Haugan; Larry R. Radloff; Harry Geyer**, all of Kalispell, MT (US)

(73) Assignee: **Semitool, Inc.**, Kalispell, MT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/300,610**

(22) Filed: **Apr. 27, 1999**

Related U.S. Application Data

(63) Continuation of application No. 08/680,057, filed on Jul. 15, 1996, now Pat. No. 5,980,706.

(51) **Int. Cl.**[7] **C25D 17/06**

(52) **U.S. Cl.** **204/297.08**; 118/729; 118/503; 204/297.01; 204/297.09; 204/297.1; 204/297.14

(58) **Field of Search** ..... 204/297 R, 297 W, 204/280, 286, 224 R, 297.01, 297.08, 297.09, 297.1, 297.14; 205/123; 118/72 B, 729, 730, 500, 503; 156/345 WH; 269/24, 27

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Assistant Examiner—William T. Leader
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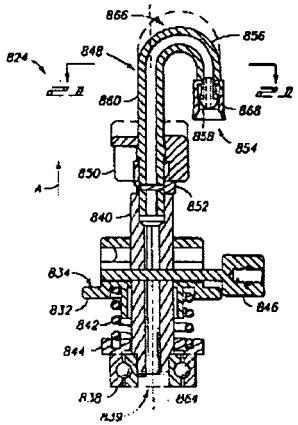
(57) **ABSTRACT**

A semiconductor workpiece holder for use in processing a semiconductor workpiece includes a workpiece support operatively mounted to support a workpiece in position for processing. A finger assembly is operatively mounted upon the workpiece support and includes a finger tip. The finger assembly is movable between an engaged position in which the finger tip is engaged against the workpiece, and a disengaged position in which the finger tip is moved away from the workpiece. Preferably, at least one electrode forms part of the finger assembly and includes an electrode contact for contacting a surface of said workpiece. At least one protective sheath covers at least some of the electrode contact. According to one aspect of the invention, a sheathed electrode having a sheathed electrode tip is positioned against a semiconductor workpiece surface in a manner engaging the workpiece surface with said sheathed electrode tip and forming a seal.

10 Claims, 20 Drawing Sheets



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US-PAT-NO: 6274013

DOCUMENT-IDENTIFIER: US 6274013 B1

TITLE: Electrode semiconductor workpiece holder

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The above described pneumatically effectuated movement of the preferred finger assemblies between the engaged and disengaged positions is but one manner of effectuating such movement. Other manners of effecuating such movement are possible.

The invention also includes novel methods for presenting a workpiece to a semiconductor process. In such methods, a workpiece is first secured to a workpiece holder. The methods work equally well for workpiece holders known in the art and for the novel workpiece holders disclosed herein.

In the next step in the sequence, the workpiece holder is rotated about a horizontal axis from an initial or first position where the workpiece holder was provided with the workpiece to a second position. The second position will be at an angle to the horizontal. The angle of the workpiece holder to the horizontal is defined by the angle between the plane of the workpiece and the horizontal. In the method, the workpiece holder is advantageously suspended about a second horizontal axis which is parallel to the first horizontal axis of the workpiece holder. At this point in the method, the angle between the first and second horizontal axes and a horizontal plane corresponds to the angle between the workpiece holder and the horizontal. The workpiece holder is then pivoted about the second horizontal axis to move the workpiece and the workpiece holder from its initial location to a final location in a horizontal plane. Advantageously, when the workpiece holder is pivoted about the second horizontal axis, the first horizontal axis also pivots about the second horizontal axis.

Preferably, during the step of rotating the workpiece holder about the first horizontal axis, the angle of the workpiece holder with respect to some known point, which is fixed with respect to the workpiece holder during the rotation process, is continually monitored. Monitoring allows for precise positioning of the workpiece holder with respect to the horizontal surface.

Likewise, during pivoting of the workpiece holder about the second horizontal axis, it is preferable that the angle defined by the line connecting the first and second horizontal axes and the horizontal plane be continually monitored. In this manner, the absolute position of the workpiece holder (and hence the workpiece itself) will be known with respect to the horizontal plane. This is important since the horizontal plane typically will contain the process to which the workpiece will be exposed.

It should be noted that in the above and following description, while the workpiece is described as being presented to a horizontal plane, it is possible that the workpiece may also be presented to a vertical plane or a plane at any angle between the vertical and the horizontal. Typically, the processing plane will be a horizontal plane due to the desire to avoid gravitational effects on process fluids to which the workpiece is exposed. In one embodiment after the workpiece has been presented to the processing plane, the workpiece holder is rotated about a spin axis to cause the workpiece to spin in the horizontal plane. Although not required in all semiconductor manufacturing processes, this is a common step which may be added in the appropriate circumstance.

The next advantageous step in the method consists of pivoting the workpiece holder about the second horizontal axis back along the path that the workpiece holder was initially pivoted along when presenting the workpiece to the horizontal process plane. There is no requirement that the workpiece holder be pivoted back to the same position whence it began, although doing so may have certain advantages as more fully A described below.

The method advantageously further consists of the step of rotating the workpiece holder about the first horizontal axis to return the workpiece to the position when it was initially presented to and engaged by the workpiece holder. It is advantageous to rotate the workpiece holder about the first axis in a direction opposite from the initial rotation of the workpiece holder.

The advantage of having the workpiece holder terminate at an end position which corresponds to the initial position when the workpiece was loaded into the workpiece holder is efficiency. That is, additional machine movements are not required to position the workpiece holder to receive a new workpiece.

The method more preferably includes the step of rotating the workpiece holder about the first horizontal axis at at least two support points along the first horizontal axis. This beneficially provides support and stability to the workpiece holder during the rotation process and subsequent movement of the apparatus.

The method also more preferably includes the step of pivoting the workpiece holder along with the first horizontal axis about the second horizontal axis at at least two support points along the second horizontal axis. This beneficially provides additional support for the workpiece holder while allowing the workpiece holder to be moved in a vertical or "Z-axis" direction.

Importantly, the only motion described in the above method is rotational motion about several axes. In the method described, there is no translational motion of the workpiece holder in a X-, Y-, or Z-axis without corresponding movement in another axis as a result of rotating through an arc.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

What is claimed is:

1. A workpiece holder for use in processing a workpiece comprising:

a workpiece support;

at least one finger assembly mounted upon said workpiece support, said at least one finger assembly including at least one contact for contacting the workpiece;

at least one finger actuator operable with said at least one finger assembly for moving said finger assembly between an engaged position wherein said finger assembly is in contact with the workpiece and a disengaged position wherein said finger assembly is disengaged from the workpiece, said at least one finger actuator having means for moving the at least one finger assembly in an axial movement toward and from the workpiece along a longitudinal axis, and means to rotate the at least one finger assembly in a rotational movement along said longitudinal axis;

at least one electrode forming a part of said at least one finger assembly, said at least one electrode having an electrode contact for contacting a surface of said workpiece to provide electrical connection therewith, wherein said electrode contact is one of said at least one contact;

at least one protective sheath covering at least a portion of the at least one finger assembly to protect the finger

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2	US 6001234 A	59			☑					USPAT

US-PAT-NO: 6274013

DOCUMENT-IDENTIFIER: US 6274013 B1

TITLE: Electrode semiconductor workpiece holder

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assembly from contact with a plating fluid, said at least one protective sheath being made from a dielectric material, said electrode contact being maintained in a generally retracted position within said at least one protective sheath when said at least one finger assembly is in said disengaged position, said electrode contact being moved out of said retracted position when said at least one finger assembly is moved into said engaged position.

2. The workpiece holder of claim 1 wherein said at least one finger actuator moves said at least one finger assembly in a reciprocal manner.

3. A workpiece holder for use in processing a workpiece comprising:

a workpiece support;

at least one finger assembly mounted upon said workpiece support, said at least one finger assembly including at least one contact for contacting the workpiece;

at least one finger actuator operable with said at least one finger assembly for moving said finger assembly between an engaged position wherein said finger assembly is in contact with the workpiece and a disengaged position wherein said finger assembly is disengaged from the workpiece, said at least one finger actuator having means for moving the at least one finger assembly in an axial movement toward and from the workpiece along a longitudinal axis, and means to rotate the at least one finger assembly in a rotational movement along said longitudinal axis;

at least one electrode forming a part of said at least one finger assembly, said at least one electrode having an electrode contact for contacting a surface of said workpiece to provide electrical connection therewith, wherein said electrode contact is one of said at least one contact;

at least one protective sheath covering at least a portion of the at least one finger assembly to protect the finger assembly from contact with a plating fluid, said at least one protective sheath being made from a dielectric material, said at least one protective sheath including a yieldable terminal adjacent said electrode contact for engaging said workpiece and effectively sealing said electrode contact therewith when said at least one finger assembly is moved to said engaged position said electrode contact being maintained in a generally retracted position within said at least one protective sheath when said at least one finger assembly is in said disengaged position, said electrode contact being moved out of said retracted position when said finger assembly is moved into said engaged position.

4. An apparatus for use in providing electrical power to a substrate while a surface of the substrate is in contact with an electrolyte pursuant to forming one or more microelectronic components on the substrate, the apparatus comprising:

one or more substrate support surfaces positioned to support the substrate as the substrate is received by or removed from the apparatus;

a contact assembly comprising

a contact actuator,

a contact member having a first end connected for actuation by the contact actuator and a second end terminating at an electrode, the contact actuator being operable to move the contact member between a first position distal the one or more substrate support surfaces to thereby allow the substrate to be received by or removed from engagement with the one or more substrate support surfaces and a second position in which the electrode is driven into electrical contact with the surface of the substrate that is to contact the electrolyte;

a dielectric sheath disposed proximate the second end of the contact member, the dielectric sheath terminating at a yieldable portion that extends beyond the electrode when the contact member is in the first position so that the electrode is retracted within a volume defined by the yieldable portion, the yieldable portion resiliently deforming when the contact member is moved to the second position, the resilient deformation being sufficient to allow the electrode to extend into electrical contact with the surface of the substrate while concurrently allowing the second end of the dielectric sheath to form a seal with the substrate to prevent the electrode from contacting the electrolyte during substrate processing.

5. The apparatus of claim 4 wherein the contact actuator moves the contact member linearly along and rotationally about a single motion axis when the contact member is moved between the first and second positions.

6. The apparatus of claim 4 wherein the one or more support surfaces are formed by a plurality of support members.

7. The apparatus of claim 4 wherein the apparatus comprises a plurality of contact assemblies.

8. The apparatus of claim 7 wherein the one or more support surfaces are formed by a plurality of support members respectively associated with each of the plurality of contact assemblies.

9. The apparatus of claim 8 wherein the plurality of support members are positioned so that the support surfaces are disposed adjacent the second end of the respective contact member when the contact member is in the second position thereby causing the substrate to be gripped therebetween during processing of the substrate.

10. The apparatus of claim 4 wherein the contact assembly and the one or more support surfaces are mounted to a common frame and extend therefrom in the same direction.

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DOCUMENT-IDENTIFIER: US 5980706 A

TITLE: Electrode semiconductor workpiece holder

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US Patent No. - PN (1):
5980706

United States Patent [19]

Bleck et al.

[11] **Patent Number: 5,980,706**

[45] **Date of Patent: Nov. 9, 1999**

[54] **ELECTRODE SEMICONDUCTOR WORKPIECE HOLDER**

[75] Inventors: **Martin Bleck; Kenneth C. Haugan; Larry R. Radloff; Harry Geyer, all of Kalispell, Mont.**

[73] Assignee: **Semitool, Inc., Kalispell, Mont.**

[21] Appl. No.: **08/680,057**

[22] Filed: **Jul. 15, 1996**

[51] **Int. Cl.**[6] **C25D 17/06**

[52] **U.S. Cl.** ..... **204/297 R**; 118/729; 118/730; 205/123

[58] **Field of Search** ..... 204/297 R, 297 W, 204/280, 286, 298.15, 224 R; 118/728, 729, 730, 500, 503; 156/345 WH; 205/118, 122, 124, 128, 136

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Primary Examiner—Kathryn Gorgos
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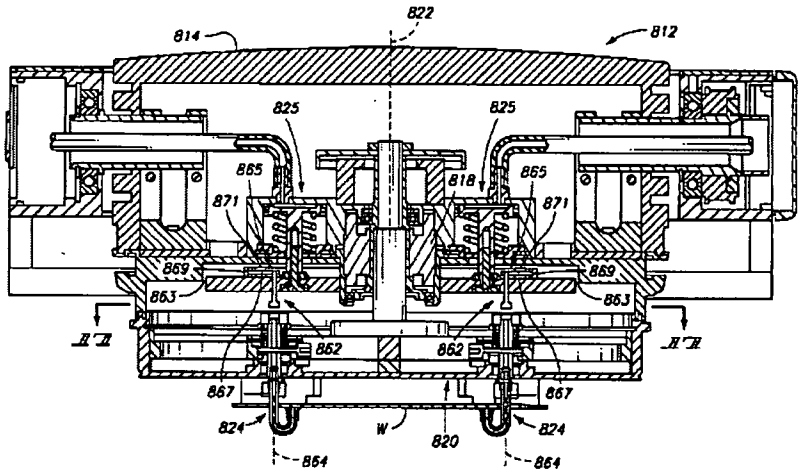
[57] **ABSTRACT**

A semiconductor workpiece holder for use in processing a semiconductor workpiece includes a workpiece support operatively mounted to support a workpiece in position for processing. A finger assembly is operatively mounted upon the workpiece support and includes a finger tip. The finger assembly is movable between an engaged position in which the finger tip is engaged against the workpiece, and a disengaged position in which the finger tip is moved away from the workpiece. Preferably, at least one electrode forms part of the finger assembly and includes an electrode contact for contacting a surface of said workpiece. At least one protective sheath covers at least some of the electrode contact. According to one aspect of the invention, a sheathed electrode having a sheathed electrode tip is positioned against a semiconductor workpiece surface in a manner engaging the workpiece surface with said sheathed electrode tip. A seal is formed about the periphery of the electrode tip, and with the electrode tip engaging the workpiece, a desired electrical contact is made to the workpiece. Thereafter, the workpiece is exposed to desired semiconductor processing conditions.

21 Claims, 20 Drawing Sheets



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US-PAT-NO: 5980706

DOCUMENT-IDENTIFIER: US 5980706 A

TITLE: Electrode semiconductor workpiece holder

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US Patent No. - PN (1):
5980706

and disengaged positions is but one manner of effectuating such movement. Other manners of effectuating such movement are possible.

The invention also includes novel methods for presenting a workpiece to a semiconductor process. In such methods, a workpiece is first secured to a workpiece holder. The methods work equally well for workpiece holders known in the art and for the novel workpiece holders disclosed herein.

In the next step in the sequence, the workpiece holder is rotated about a horizontal axis from an initial or first position where the workpiece holder was provided with the workpiece to a second position. The second position will be at an angle to the horizontal. The angle of the workpiece holder to the horizontal is defined by the angle between the plane of the workpiece and the horizontal. In the method, the workpiece holder is advantageously suspended about a second horizontal axis which is parallel to the first horizontal axis of the workpiece holder. At this point in the method, the angle between the first and second horizontal axes and a horizontal plane corresponds to the angle between the workpiece holder and the horizontal. The workpiece holder is then pivoted about the second horizontal axis to move the workpiece and the workpiece holder from its initial location to a final location in a horizontal plane. Advantageously, when the workpiece holder is pivoted about the second horizontal axis, the first horizontal axis also pivots about the second horizontal axis.

Preferably, during the step of rotating the workpiece holder about the first horizontal axis, the angle of the workpiece holder with respect to some known point, which is fixed with respect to the workpiece holder during the rotation process, is continually monitored. Monitoring allows for precise positioning of the workpiece holder with respect to the horizontal surface.

Likewise, during pivoting of the workpiece holder about the second horizontal axis, it is preferable that the angle defined by the line connecting the first and second horizontal axes and the horizontal plane be continually monitored. In this manner, the absolute position of the workpiece holder (and hence the workpiece itself) will be known with respect to the horizontal plane. This is important since the horizontal plane typically will contain the process to which the workpiece will be exposed.

It should be noted that in the above and following description, while the workpiece is described as being presented to a horizontal plane, it is possible that the workpiece may also be presented to a vertical plane or a plane at any angle between the vertical and the horizontal. Typically, the processing plane will be a horizontal plane due to the desire to avoid gravitational effects on process fluids to which the workpiece is exposed. In one embodiment after the workpiece has been presented to the processing plane, the workpiece holder is rotated about a spin axis to cause the workpiece to spin in the horizontal plane. Although not required in all semiconductor manufacturing processes, this is a common step which may be added in the appropriate circumstance.

The next advantageous step in the method consists of pivoting the workpiece holder about the second horizontal axis back along the path that the workpiece holder was initially pivoted along when presenting the workpiece to the horizontal process plane. There is no requirement that the workpiece holder be pivoted back to the same position whence it began, although doing so may have certain advantages as more fully described below.

The method advantageously further consists of the step of rotating the workpiece holder about the first horizontal axis to return the workpiece to the position when it was initially presented to and engaged by the workpiece holder. It is advantageous to rotate the workpiece holder about the first axis in a direction opposite from the initial rotation of the workpiece holder.

The advantage of having the workpiece holder terminate at an end position which corresponds to the initial position when the workpiece was loaded into the workpiece holder is efficiency. That is, additional machine movements are not required to position the workpiece holder to receive a new workpiece.

The method more preferably includes the step of rotating the workpiece holder about the first horizontal axis at at least two support points along the first horizontal axis. This beneficially provides support and stability to the workpiece holder during the rotation process and subsequent movement of the apparatus.

The method also more preferably includes the step of pivoting the workpiece holder along with the first horizontal axis about the second horizontal axis at at least two support points along the second horizontal axis. This beneficially provides additional support for the workpiece holder while allowing the workpiece holder to be moved in a vertical or "Z-axis" direction.

Importantly, the only motion described in the above method is rotational motion about several axes. In the method described, there is no translational motion of the workpiece holder in a X-, Y-, or Z-axis without corresponding movement in another axis as a result of rotating through an arc.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

We claim:

1. A workpiece holder for use in processing a workpiece comprising:

a movable workpiece support mounted for movement between a processing position which is used to support a workpiece in position for processing and an open position wherein the workpiece support is open and available for loading and unloading a workpiece to and from the workpiece support;

at least one finger assembly mounted upon said movable workpiece support, said at least one finger assembly including at least one electrode having an electrode contact for contacting a surface of said workpiece to provide electrical connection therewith;

at least one finger actuator operable with said at least one finger assembly for moving said finger assembly between an engaged position wherein said finger assembly is in contact with the workpiece and a disengaged position wherein said finger assembly is disengaged from the workpiece, said at least one finger actuator having means for moving the at least one finger assembly in an axial movement toward and from the workpiece and means to rotate the at least one finger assembly in a rotational movement.

2. The workpiece holder of claim 1 wherein said at least one finger actuator moves said at least one finger assembly in a reciprocal manner.

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3. The workpiece holder of claim 1, wherein said means to rotate the at least one finger assembly rotates the finger assembly about a pivot axis which is aligned with the axial movement produced by said means for moving the at least one finger assembly in an axial movement.

4. The workpiece holder of claim 1 further comprising at least one protective sheath covering at least a portion of the at least one finger assembly to protect the finger assembly from contact with a plating fluid, said at least one protective sheath being made from a dielectric material.

5. The workpiece holder of claim 4, wherein said at least one protective sheath includes a rim portion for engaging said workpiece and forming a seal therebetween.

6. The workpiece holder of claim 4, wherein said electrode contact is maintained in a generally retracted position within said at least one protective sheath when said at least one finger assembly is in said disengaged position; said electrode contact being moved out of said retracted position when said at least one finger assembly is moved into said engaged position.

7. The workpiece holder of claim 4, wherein said at least one protective sheath includes a yieldable terminal end adjacent said electrode contact for engaging said workpiece and effectively sealing said electrode contact therewithin when said at least one finger assembly is moved to said engaged position; wherein said electrode contact is maintained in a generally retracted position within said at least one protective sheath when said at least one finger assembly is in said disengaged position; said electrode contact being moved out of said retracted position when said finger assembly is moved into said engaged position.

8. The workpiece holder of claim 1, wherein said at least one finger assembly comprises:

a finger assembly frame;

a collet movably mounted on said finger assembly frame for longitudinal reciprocation into and out of said engaged position;

a finger secured to said collet and movable thereby, a portion of said finger extending generally away from said collet; and

a bend in said finger between said collet and said contact.

9. The workpiece holder of claim 1, wherein said movable workpiece support includes a rotor operatively mounted for rotation about a rotor axis; said rotor moving said workpiece about said rotor axis for processing.

10. The workpiece holder of claim 1, wherein:

said movable workpiece support includes a rotor operatively mounted for rotation about a rotor axis; said rotor rotating said workpiece for processing; and

there are plural finger assemblies and plural finger actuators.

11. A workpiece holder for use in a plating process to hold and provide electrical contact with a workpiece, comprising:

a movable workpiece support mounted for powered movement between a processing position wherein the workpiece support is placed in relationship with a processing bowl, and an open position wherein the workpiece support is removed from the processing bowl and available for loading and unloading a workpiece to and from the workpiece support;

a workpiece support operator for powering movement of the movable workpiece support between said processing position and said open position;

a rotor mounted for rotational movement upon the movable workpiece support to allow the workpiece support and a workpiece supported thereon to be rotated during processing;

at least one finger assembly mounted upon said rotor, said at least one finger assembly including at least one contact for contacting the workpiece;

at least one finger actuator mounted upon the movable workpiece support, said at least one finger actuator being controllably movable to effect movement of the at least one finger assembly between an engaged position wherein the at least one finger assembly engages the workpiece and a disengaged position wherein the at least one finger assembly is disengaged from the workpiece to allow the workpiece to be loaded and unloaded from the workpiece support;

at least one electrode forming a part of said at least one finger assembly, said at least one electrode having an electrode contact for contacting a surface of said workpiece to provide electrical connection therewith, wherein said electrode contact is one of said at least one contact.

12. A workpiece holder according to claim 11 wherein there are a plurality of finger assemblies and finger actuators.

13. A workpiece holder according to claim 11 wherein said at least one finger actuator is controllably engaged and disengaged with the at least one finger assembly mounted upon the rotor.

14. A workpiece holder according to claim 11 wherein said at least one finger actuator includes means for moving the at least one finger assembly in an axial movement toward and from the workpiece.

15. A workpiece holder according to claim 11 wherein said at least one finger actuator includes means to rotate the at least one finger assembly in a rotational movement.

16. A workpiece holder according to claim 11 wherein said at least one finger actuator includes means for moving the at least one finger assembly in an axial movement toward and from the workpiece and means to rotate the at least one finger assembly in a rotational movement.

17. A workpiece holder according to claim 11 and further comprising at least one protective sheath covering at least a portion of the at least one finger assembly to protect the finger assembly from contact with a plating fluid, said at least one protective sheath being made from a dielectric material.

18. A workpiece holder according to claim 17 wherein there are a plurality of finger assemblies and finger actuators.

19. A workpiece holder according to claim 17 wherein said at least one protective sheath includes a rim portion for engaging said workpiece and forming a seal therebetween.

20. A workpiece holder according to claim 17 wherein said electrode contact is maintained in a generally retracted position within said at least one protective sheath when said at least one finger assembly is in said disengaged position; said electrode contact being moved out of said retracted position when said at least one finger assembly is moved into said engaged position.

21. A workpiece holder according to claim 17 wherein said at least one protective sheath includes a yieldable terminal end adjacent said electrode contact for engaging said workpiece and effectively sealing said electrode contact therewithin when said at least one finger assembly is moved to said engaged position; wherein said electrode contact is maintained in a generally retracted position within said at least one protective sheath when said at least one finger assembly is in said disengaged position; said electrode contact being moved out of said retracted position when said finger assembly is moved into said engaged position.

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US-PAT-NO: 5985126

DOCUMENT-IDENTIFIER: US 5985126 A

TITLE: Semiconductor plating system workpiece support having workpiece engaging electrodes with distal contact part and dielectric cover

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US Patent No. - PN (1):
5985126

United States Patent [19]

Bleck et al.

[11] **Patent Number: 5,985,126**

[45] **Date of Patent: Nov. 16, 1999**

[54] **SEMICONDUCTOR PLATING SYSTEM WORKPIECE SUPPORT HAVING WORKPIECE ENGAGING ELECTRODES WITH DISTAL CONTACT PART AND DIELECTRIC COVER**

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[73] Assignee: **Semitool, Inc.**, Kalispell, Mont.

[21] Appl. No.: **08/988,333**

[22] Filed: **Sep. 30, 1997**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/680,057, Jul. 15, 1996.

[51] **Int. Cl.**[6] **C25D 7/12**; C25D 17/06

[52] **U.S. Cl.** ..... **205/123**; 204/224 R; 204/297 R; 205/157

[58] **Field of Search** ..... 205/123, 143, 205/157, 291; 204/224 R, 285, 287, 297 R, 297 W; 118/500, 503, 728, 730

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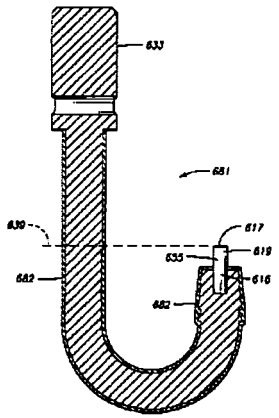
Primary Examiner—Kathryn Gorgos
Assistant Examiner—William T. Leader
Attorney, Agent, or Firm—Rockey, Milnamow & Katz, Ltd.

[57] **ABSTRACT**

A semiconductor workpiece holder used in electroplating systems for plating metal layers onto a semiconductor workpieces, and is of particular advantage in connection with plating copper onto semiconductor materials. The workpiece holder includes electrode assemblies which have a contact part which connects to a distal end of an electrode shaft and bears against the workpiece and conducts current therebetween. The contact part is preferably made from a corrosion resistant material, such as platinum. The electrode assembly also preferably includes a dielectric layer which covers the distal end of the electrode shaft and seals against the contact part to prevent plating liquid from corroding the joint between these parts.

28 Claims, 38 Drawing Sheets



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US-PAT-NO: 5985126

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TITLE: Semiconductor plating system workpiece support having workpiece engaging electrodes with distal contact part and dielectric cover

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chamber 345 is sensed by two level detectors 351 and 352. One level detector is used to sense a desired high level and the other is used to sense an overfull condition. The level of liquid is preferably maintained within a desired range for stability of operation. This can be done using several different outflow configurations. A preferred configuration is to sense the high level using detector 351 and then drain fluid through a drain line as controlled by a control valve. It is also possible to use a standpipe arrangement (not illustrate), and such is used as a final overflow protection device in the preferred plating station 303. More complex level controls are also possible.

The outflow liquid from chamber 345 is preferably returned to a suitable reservoir. The liquid can then be treated with additional plating chemicals or other constituents of the plating or other process liquid and used again.

The plating bowl assembly 303 further includes an anode 334. In the preferred uses according to this invention, the anode is a consumable anode used in connection with the plating of copper or other metals onto semiconductor materials. The specific anode will vary depending upon the metal being plated and other specifics of the plating liquid being used. A number of different consumable anodes which are commercially available may be used as anode 334.

FIG. 42 also shows a diffusion plate 375 provide above the anode 334 for rendering the fluid plating bath above the diffusion plate with less turbulence. Fluid passages are provided over all or a portion of the diffusion plate to allow fluid communication therethrough. The height of the diffusion plate is adjustable using three diffuser height adjustment mechanisms 386 and secured by three mounting fasteners 389.

Plating Anode Shield

The invention also includes an anode shield 393 which can be secured to the consumable anode 334 using anode shield fasteners 394. The anode shield and anode shield fasteners are preferably made from a dielectric material, such as polyvinylidene fluoride or polypropylene. The anode shield is advantageously about 2–5 millimeters thick, more preferably about 3 millimeters thick.

The anode shield serves to electrically isolate and physically protect the back side of the anode. It also reduces the consumption of organic plating liquid additives consumed. Although the exact mechanism may not be known at this time, the anode shield is believed to prevent disruption of certain materials which develop over time on the back side of the anode. If the anode is left unshielded the organic chemical plating additives are consumed at a significantly greater rate. With the shield in place these additive are consumed less. The shield is preferably positioned on the anode so as to shield it from direct impingement by the incoming plating liquid.

The invention thus also include methods for plating which include other method steps described herein in combination with shielding a consumable anode from direct flow of plating liquids using a dielectric anode shield.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

We claim:

1. A semiconductor workpiece holder for use in a semiconductor electroplating apparatus used to plate a metal or metals onto a semiconductor workpiece, comprising:

a workpiece support mounted to support a semiconductor workpiece in position with at least a processed surface of the workpiece being in contact with a plating bath;

at least one electrode finger which is electrically conductive and capable of receiving and conducting electrical current therethrough; said at least one electrode finger having an electrode shaft which extends toward a distal end;

a contact part mounted to the distal end of the electrode shaft to provide an electrical contact face which bears upon the semiconductor workpiece during processing to communicate electrical current therethrough.

2. A semiconductor workpiece holder according to claim 1 wherein said contact part is made from a corrosion resistant metal.

3. A semiconductor workpiece holder according to claim 1 wherein said contact part is made from platinum.

4. A semiconductor workpiece holder according to claim 1 wherein said electrode shaft is made from a stainless steel or titanium.

5. A semiconductor workpiece holder according to claim 1 wherein:

said contact part is made from platinum;

said electrode shaft is made from a stainless steel or titanium.

6. A semiconductor workpiece holder according to claim 1 and further comprising a dielectric layer formed about at least the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

7. A semiconductor workpiece holder according to claim 1 and further comprising a dielectric layer formed from a dielectric plastic material about at least the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

8. A semiconductor workpiece holder according to claim 1 and further comprising a dielectric layer formed from polyvinylidene fluoride about at least the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

9. A semiconductor workpiece holder according to claim 1 and further comprising a dielectric layer coated about at least the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

10. A semiconductor workpiece holder for use in a semiconductor electroplating apparatus used to plate a copper material onto a semiconductor workpiece, comprising:

a workpiece support mounted to support a semiconductor workpiece in position with at least a processed surface of the workpiece being in contact with a plating bath;

at least one electrode finger which is electrically conductive and capable of receiving and conducting electrical current therethrough; said at least one electrode finger having an electrode shaft which extends toward a distal end;

a contact part mounted to the distal end of the electrode shaft to provide an electrical contact face which bears

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upon the semiconductor workpiece during processing to communicate electrical current therethrough.

11. A semiconductor workpiece holder according to claim 10 wherein said contact part is made from a corrosion resistant metal.

12. A semiconductor workpiece holder according to claim 10 wherein said contact part is made from platinum.

13. A semiconductor workpiece holder according to claim 10 and further comprising a dielectric layer formed about the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

14. A semiconductor workpiece holder according to claim 10 and further comprising a dielectric layer formed from a dielectric plastic material about the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

15. A semiconductor workpiece holder according to claim 10 and further comprising a dielectric layer formed from polyvinylidene fluoride about the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

16. A semiconductor workpiece holder according to claim 10 and further comprising a dielectric layer coated about the distal end of the electrode shaft and forming a seal against side walls of the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

17. A semiconductor workpiece holder for use in a semiconductor electroplating apparatus used to plate a metal or metals onto a semiconductor workpiece, comprising:

a workpiece support mounted to support a semiconductor workpiece in position with at least a processed surface of the workpiece being in contact with a plating bath;

at least one electrode finger which is electrically conductive and capable of receiving and conducting electrical current therethrough; said at least one electrode finger having an electrode shaft which extends toward a distal end;

a contact part mounted to the distal end of the electrode shaft to provide an electrical contact face which bears upon the semiconductor workpiece during processing to communicate electrical current therethrough;

a dielectric layer formed about at least the distal end of the electrode shaft and against the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

18. A semiconductor workpiece holder according to claim 17 wherein said contact part is made from a corrosion resistant metal.

19. A semiconductor workpiece holder according to claim 17 wherein said contact part is made from platinum.

20. A semiconductor workpiece holder according to claim 17 wherein said electrode shaft is made from a stainless steel or titanium.

21. A semiconductor workpiece holder according to claim 17 wherein:

said contact part is made from platinum;

said electrode shaft is made from a stainless steel or titanium.

22. A semiconductor workpiece holder for use in a semiconductor electroplating apparatus used to plate a metal or metals onto a semiconductor workpiece, comprising:

a workpiece support mounted to support a semiconductor workpiece in position with at least a processed surface of the workpiece being in contact with a plating bath;

at least one electrode finger which is electrically conductive and capable of receiving and conducting electrical current therethrough; said at least one electrode finger having an electrode shaft which extends toward a distal end;

a contact part mounted to the distal end of the electrode shaft to provide an electrical contact face which bears upon the semiconductor workpiece during processing to communicate electrical current therethrough;

means forming a dielectric covering about at least the distal end of the electrode shaft and against the contact part to exclude plating liquid from a joint formed between the electrode shaft and the contact part.

23. A method for plating a metal onto the surface of a semiconductor workpiece, comprising:

contacting a surface of the semiconductor workpiece with an electrode assembly; said contacting being performed using a contact face formed upon a contact part, said contact part being mounted to a distal end of an electrode shaft at a contact part joint existing between the electrode shaft and the contact part; said electrode assembly further having a dielectric layer formed about the distal end of the electrode shaft and in sealing relationship against the contact part;

submersing a processed surface of the semiconductor workpiece into a plating bath liquid which is used to plate a metal onto the processed surface of the semiconductor workpiece;

excluding plating bath liquid from the contact part joint using said dielectric layer;

electroplating a metal onto the semiconductor workpiece by passing electrical current through the contact part and between the semiconductor workpiece and the electrode assembly.

24. A method according to claim **23** wherein said contact part is made from a noncorrosive metal.

25. A method according to claim **23** wherein said contact part is made from platinum.

26. A method for plating copper onto the surface of a semiconductor workpiece, comprising:

contacting a surface of the semiconductor workpiece with an electrode assembly; said contacting being performed using a contact face formed upon a contact part, said contact part being mounted to a distal end of an electrode shaft at a contact part joint existing between the electrode shaft and the contact part; said electrode assembly further having a dielectric layer formed about the distal end of the electrode shaft and in sealing relationship against the contact part;

submersing a processed surface of the semiconductor workpiece into a plating bath liquid which is used to plate copper onto the processed surface of the semiconductor workpiece;

excluding plating bath liquid from the contact part joint using said dielectric layer;

electroplating copper onto the semiconductor workpiece by passing electrical current through the contact part and between the semiconductor workpiece and the electrode assembly.

27. A method according to claim **26** wherein said contact part is made from a noncorrosive metal.

28. A method according to claim **26** wherein said contact part is made from platinum.

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6	US 0627401 A	3						☑					USPAT

US-PAT-NO: 6080291

DOCUMENT-IDENTIFIER: US 6080291 A

TITLE: Apparatus for electrochemically processing a workpiece including an electrical contact assembly having a seal member

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US Patent No. - PN (1):
6080291

United States Patent [19]

Woodruff et al.

[11] **Patent Number: 6,080,291**

[45] **Date of Patent: Jun. 27, 2000**

[54] **APPARATUS FOR ELECTROCHEMICALLY PROCESSING A WORKPIECE INCLUDING AN ELECTRICAL CONTACT ASSEMBLY HAVING A SEAL MEMBER**

[75] Inventors: **Daniel J. Woodruff**; **Kyle M. Hanson**, both of Kalispell, Mont.

[73] Assignee: **Semitool, Inc.**, Kalispell, Mont.

[21] Appl. No.: **09/113,723**

[22] Filed: **Jul. 10, 1998**

[51] **Int. Cl.**[7] **C25D 17/04**; C25D 17/06

[52] **U.S. Cl.** **204/297.01**; 204/212

[58] **Field of Search** ..... 204/297 R

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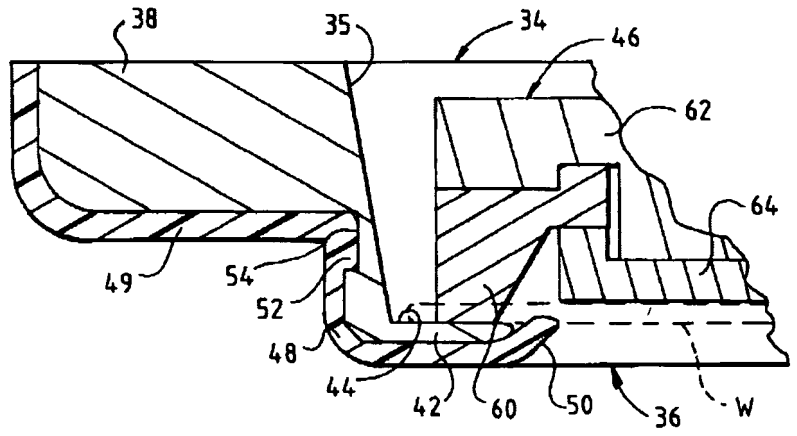
Attorney, Agent, or Firm—Rockey, Milnamow & Katz, Ltd.

[57] **ABSTRACT**

A plating apparatus, such as for electroplating of semiconductor wafers or like workpieces, includes a plating contact including an annular contact ring having an annular mounting portion, and an annular electrically-conductive contact portion extending inwardly of the mounting portion. The contact portion is configured for substantially continuous electrically-conductive contact with a peripheral region of the associated workpiece. The arrangement further includes an annular seal member mounted on the annular contact ring, with the seal member including a resiliently deformable annular seal lip portion adjacent to the contact portion of the contact ring. The seal lip is resiliently biased into continuous sealing engagement with the peripheral region of the workpiece when the workpiece is positioned in electrically-conductive contact with the contact ring. The apparatus includes a rotor assembly configured to receive the workpiece, and move the workpiece into operative contact with the annular contact ring and the annular seal member.

8 Claims, 13 Drawing Sheets



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US-PAT-NO: 6080291

DOCUMENT-IDENTIFIER: US 6080291 A

TITLE: Apparatus for electrochemically processing a workpiece including an electrical contact assembly having a seal member

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By this arrangement, the actuation ring **82** of the detachable portion **70** can be coupled to, and uncoupled from, the actuation coupling **106** of the rotor assembly.

Actuation coupling **106** is movable in a direction in opposition to the biasing springs **86** by a plurality of pneumatic actuators **108** mounted on a frame **110** of the rotor assembly. Each actuator **108** is operatively connected with the actuation coupling **106** by a respective drive member **112**, each of which extends generally through the frame **110** on which motor **102** is mounted.

Operation of the rotor assembly **28** will be appreciated from the above description. Loading of workpiece W into the rotor assembly is effected with the rotor assembly in a generally upwardly facing orientation, such as illustrated in FIGS. 2 and 13. Workpiece W is moved transversely through the opening **76** defined by the rotor assembly to a position wherein the workpiece is positioned in spaced relationship generally above supports **80**. The robotic arm **32** is then lowered (with clearance opening **78** accommodating such movement), whereby the workpiece is positioned upon the supports **80**. The robotic arm can then be withdrawn from within the rotor assembly.

The workpiece is now moved perpendicularly to the first direction in which it is moved transversely into the rotor assembly. Such movement is effected by movement of backing member **46** generally toward contact ring **34** and seal member **36**. It is presently preferred that pneumatic actuators **102** act in opposition to biasing springs **86** which are operatively connected by actuation ring **82** and shafts **84** to the backing member **46**. Thus, actuators **108** are operated to permit springs **86** to bias and urge actuation ring **82**, and thus backing member **46**, toward contact ring **34**. FIG. **13** illustrates the disposition of the workpiece W within the rotor assembly after it is received therein on supports **80**, while FIG. **14** illustrates the disposition of the workpiece after it has been moved by backing member **46**, under the influence of springs **86**, into the processing position. As will be observed, the workpiece is moved into electrically conductive relationship with the contact portion **42** of the contact ring **34**, with seal member **36** sealingly engaging the peripheral portion of the workpiece. The workpiece is held firmly in position against the contact member under the influence of springs **86**, while pneumatic actuators **108** are depressurized.

In the preferred form, the connection between actuation ring **82** and backing member **46**, by shafts **84**, permits some "float", that is, the actuation ring and backing member are not rigidly joined to each other. This preferred arrangement accommodates the common tendency of the pneumatic actuators **108** to move at slightly different speeds, thus assuring that the workpiece is urged into substantial uniform contact with the contact member **34**, while avoiding excessive stressing of the workpiece, or binding of the actuation mechanism.

With the workpiece firmly held between the backing member **46** and the contact ring **34** (and seal member **36**), lift and rotate apparatus **30** rotates the rotor assembly **28**, and rotates and lowers the rotor assembly into cooperative position with reactor vessel **12** so that the surface of the workpiece is placed in contact with plating solution within the reactor vessel. FIG. **18** illustrates the apparatus in this condition. Because the peripheral seal **36** acts to seal the entire peripheral region of the workpiece, it is important that any gas which accumulates on the surface of the workpiece be permitted to vent and escape. Accordingly, practice of the present invention contemplates that the surface of the workpiece be disposed at an acute angle (angle "alpha" in FIG. **16**), such as on the order of two degrees from horizontal, with respect to the surface of the solution in the reactor vessel. This facilitates venting of gas from the surface of the workpiece during the plating process as the workpiece, and associated backing and contact members, are rotated in unison by motor **102** acting through drive shaft **100** and the housing assembly **72**, **73**. Circulation of plating solution within the reactor vessel, as electrical current is passed through the workpiece and the plating solution, effects the desired electroplating of a metal layer on the surface of the workpiece.

A number of features of the present invention facilitate efficient and cost-effective electroplating of workpieces such as semiconductor wafers. By use of a contact ring having substantially continuous contact, either in the form of continuous contact ring **34**, or contact ring **134** having discrete contact regions, a high number of plating contacts are provided while minimizing the required number of components. The actuation of the backing member **46** is desirably effected by a simple linear motion, thus facilitating precise positioning of the workpiece, and uniformity of contact with the contact ring. The illustrated arrangement desirably minimizes the "penetrations" through the rotor assembly into the chemical environment within the reactor vessel, thereby desirably minimizing the required sealing of these regions. Disassembly is facilitated by the detachable configuration of the portion **70** of the rotor assembly, with the arrangement further facilitating the provision of different contact configurations by simply changing the contact ring **34**, **134**. The ring contact provides ideal distribution of contact onto the surface of the workpiece, while the preferred provision of the peripheral seal can protect the contact from plating solution, thereby desirably preventing build-up of plated material onto the electrical contacts. The perimeter seal also desirably prevents plating onto the peripheral portion of the workpiece. The contact assembly is desirably formed from a minimum number of components, and contact with the workpiece can be tightly controlled, which is important in those applications in which only a specified region of the workpiece is provided by electric contact.

From the foregoing, it will be observed that numerous modifications and variations can be made without departing from the true spirit and scope of the novel concept of the present invention. It will be understood that no limitation with respect to the specific embodiments illustrated herein is intended or should be inferred. The disclosure is intended to cover, by the appended claims, all such modifications as fall within the scope of the claims.

What is claimed is:

1. An electrical contact assembly for an apparatus for effecting electrochemical processing of a workpiece, comprising:

an annular contact for mounting on said apparatus, said annular contact having an annular mounting portion, and an annular electrically-conductive contact portion extending inward of said mounting portion, said contact portion being configured for electrically-conductive contact with a peripheral region of said workpiece at a substantial number of contact points; and

an annular seal member mounted on said annular contact, the annular seal member comprising an annular seal lip formed entirely from a resiliently deformable material, the annular seal lip comprising an upstanding portion in fixed alignment with the annular mounting portion of the annular contact and a radially extending portion

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US-PAT-NO: 6080291

DOCUMENT-IDENTIFIER: US 6080291 A

TITLE: Apparatus for electrochemically processing a workpiece including an electrical contact assembly having a seal member

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extending from the upstanding portion that terminates at an upstanding edge adjacent and radially interior to said contact portion of said annular contact, the annular seal lip generally deforming about one or more flex points on the upstanding portion of the annular seal lip as the workpiece is driven into engagement with the upstanding edge of the seal lip and into electrical contact with the contact portion of the annular contact so that said seal lip is resiliently biased into continuous sealing engagement with the peripheral region of said workpiece, such sealing engagement inhibiting contact between the contact portion of the annular contact and a processing fluid used in the electrochemical processing of the workpiece.

2. A plating contact in accordance with claim 1, wherein annular contact ring includes a conic guide surface for guiding said workpiece into centered relationship with said seal member.

3. A plating contact in accordance with claim 1, including means for releasably retaining said seal member on said annular contact ring.

4. A plating contact in accordance with claim 3, wherein said retaining means comprises at least one retention projection on one of said contact ring and said seal member, and at least one recess defined by the other of said contact ring and said seal member for releasably, resiliently receiving said retention projection.

5. An electrical contact assembly for an apparatus for effecting electrochemical processing of a workpiece, comprising:

an annular contact for mounting on said apparatus, said annular contact having an annular mounting portion, and an annular, electrically-conductive contact portion extending inwardly of said mounting portion and having a generally upwardly facing surface con figured for electrically-conductive contact with a peripheral region of said associated workpiece at a substantial number of contact points; and

an annular seal member mounted on said annular contact, the annular seal member comprising an annular seal lip formed entirely from a resiliently deformable material selected from a group consisting of polymeric and elastomeric materials, the annular seal lip comprising an upstanding portion and a radially extending portion extending from the upstanding portion and terminating at an upstanding edge adjacent and radially interior to said contact portion of said annular contact,

one of said annular contact and said annular seal member comprising at least one retention projection, and the other of said annular contact and said annular seal member defining at least one recess for resiliently receiving said retention projection to thereby join the upstanding portion of the annular seal member to the mounting portion of the annular contact, the annular seal lip generally deforming about one or more flex point on the upstanding portion of the annular sealing lip as the workpiece is driven into engagement with the upstanding edge of the seal lip and into electrical contact with the contact portion of the annular contact so that the sealing lip is resiliently biased into continuous sealing engagement with the peripheral region of said workpiece, such sealing engagement inhibiting contact between the contact portion of the annular contact and a processing fluid used in the electrochemical processing of the workpiece.

6. A plating contact in accordance with claim 5, wherein said contact portion of said contact ring is configured for continuous, uninterrupted electrically-conductive contact with the peripheral region of said workpiece.

7. A plating contact in accordance with claim 5, wherein said contact portion of said contact ring includes a plurality of discrete contact regions.

8. An electrical contact assembly for an apparatus for effecting electrochemical processing of a workpiece, comprising:

an integral contact member having an electrically conductive mounting portion and an electrically-conductive contact portion and electrical contact with and extending inward of the mounting portion, the contact portion having one or more contacts configured for electrically-conductive contact with a peripheral region of the workpiece at a substantial number of contact points; and

an integral seal member comprising a seal lip formed entirely from a resiliently deformable material, the seal lip comprising an upstanding portion in fixed alignment with the mounting portion of the annular contact and a radially extending portion extending from the upstanding portion that terminates at an upstanding edge adjacent and radially interior to the one or more contacts of the contact portion of the integral contact, the seal lip generally deforming about one or more flex points of the upstanding portion of the seal lip as the workpiece is driven into engagement with the upstanding edge of the seal lip and into electrical contact with the contacts of the integral contact so that the seal lip is resiliently biased into continuous sealing engagement with the peripheral region of the workpiece to thereby inhibit contact between a processing fluid used to electrochemically process the workpiece and the contacts of the integral contact.

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US-PAT-NO: 6309524

DOCUMENT-IDENTIFIER: US 6309524 B1
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TITLE: Methods and apparatus for processing the surface of a microelectronic workpiece

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US Patent No. - PN (1):
6309524

(12) **United States Patent**
Woodruff et al.

(10) **Patent No.: US 6,309,524 B1**
(45) **Date of Patent: *Oct. 30, 2001**

(54) **METHODS AND APPARATUS FOR PROCESSING THE SURFACE OF A MICROELECTRONIC WORKPIECE**

(75) Inventors: **Daniel J. Woodruff**; **Kyle M. Hanson**; **Thomas H. Oberlitner**; **LinLin Chen**; **John M. Pedersen**, all of Kalispell, MT (US); **Vladimir Zila**, Scarborough (CA)

(73) Assignee: **Semitool, Inc.**, Kalispell, MT (US)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/386,610**

(22) Filed: **Aug. 31, 1999**

Related U.S. Application Data

(63) Continuation of application No. PCT/US99/15847, filed on Jul. 12, 1999, which is a continuation of application No. 09/113,723, filed on Jul. 10, 1998, now Pat. No. 6,080,291.
(60) Provisional application No. 60/111,232, filed on Dec. 7, 1998, and provisional application No. 60/119,668, filed on Feb. 11, 1999.

(51) **Int. Cl.**[7] **C25D 17/04**; C25D 17/06

(52) **U.S. Cl.** **204/297.1**; 204/297.09

(58) **Field of Search** ..... **8204/297 R, 279, 204/297.01, 297.09, 297.06, 297.1**

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Primary Examiner—Donald R. Valentine
Assistant Examiner—Erica Smith-Hicks
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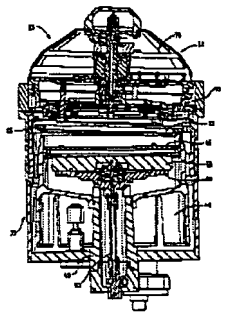
(57) **ABSTRACT**

A reactor for plating a metal onto a surface of a workpiece is set forth. The reactor comprises a reactor bowl including an electroplating solution disposed therein and an anode disposed in the reactor bowl in contact with the electroplating solution. A contact assembly is spaced from the anode within the reactor bowl. The contact assembly includes a plurality of contacts disposed to contact a peripheral edge of the surface of the workpiece to provide electroplating power to the surface of the workpiece. The contacts execute a wiping action against the surface of the workpiece as the workpiece is brought into engagement therewith. The contact assembly also including a barrier disposed interior of the plurality of contacts. The barrier includes a member disposed to engage the surface of the workpiece to assist in isolating the plurality of contacts from the electroplating solution. In one embodiment, the plurality of contacts are in the form of discrete flexures while in another embodiment the plurality of contacts are in the form of a Belleville ring contact. A flow path may be provided in the contact assembly for providing a purging gas to the plurality of contacts and the peripheral edge of the workpiece. The purging gas may be used to assist in the formation of the barrier of the contact assembly. A combined electroplating/electroless plating tool and method are also set forth.

39 Claims, 26 Drawing Sheets



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may be supplied directly through a hollowed region of drive shaft **360** as opposed to an intermediate tube. Depending on the particular implementation of the rotor assembly **75**, communication of the purging gas may then proceed to the purge port through a corresponding tube or through a hollow channel formed in a substantially solid body member that spans therebetween.

Communication of the purging gas from purge port **725** to the isolated regions of the corresponding workpiece holder or contact assembly is illustrated in FIG. **46**. As shown, purge port **725** opens to a purge passageway **735** that is disposed through an outer housing of the rotor assembly **75**. The purge passageway **735** opens to an inlet port **740** of the workpiece holder or contact assembly (such inlet ports are also illustrated in the embodiments of the workpiece holders and contact assemblies described above). From such inlet ports, the purge gas flows through the particular holder or contact assembly in the manner described above.

Integrated Plating Tool

FIGS. **47** through **49** are top plan views of integrated processing tools, shown generally at **1450**, **1455**, and **1500** that may incorporate electroless plating reactors and electroplating reactors as a combination for plating on a microelectronic workpiece, such as a semiconductor wafer. Processing tools **1450** and **1455** are each based on tool platforms developed by Semitool, Inc., of Kalispell, Mont. The processing tool platform of the tool **450** is sold under the trademark LT-210™, the processing tool platform of the tool **1455** is sold under the trademark LT-210C™, and the processing tool **1500** is sold under the trademark EQUINOX™. The principal difference between the tools **1450**, **1455** is in the footprints required for each. The platform on which tool **1455** is based has a smaller footprint than the platform on which tool **1455** is based. Additionally, the platform on which tool **1450** is based is modularized and may be readily expanded. Each of the processing tools **1450**, **4155**, and **1500** are computer programmable to implement user entered processing recipes.

Each of the processing tools **1145**, **1455**, and **1500** include an input/output section **1460**, a processing section **1465**, and one or more robots **1470**. The robots **1470** for the tools **1450**, **1455** move along a linear track. The robot **1470** for the tool **1500** is centrally mounted and rotates to access the input/output section **1460** and the processing section **1465**. Each input/output section **1460** is adapted to hold a plurality of workpieces, such as semiconductor wafers, in one or more workpiece cassettes. Processing section **1465** includes a plurality of processing stations **1475** that are used to perform one or more fabrication processes on the semiconductor wafers. The robots **1470** are used to transfer individual wafers from the workpiece cassettes at the input/output section **1460** to the processing stations **1475**, as well as between the processing stations **1475**.

One or more of the processing stations **1475** can be configured as electroless plating reactor **1475***a* such as heretofore described, and one or more of the processing stations can be configured as electroplating assemblies, **1475***b* such as the electroplating reactor described above. For example, each of the processing tools **1450** and **1455** may include three electroless plating reactors, three electroplating reactors and one or more pre-wet/rinse station or other processing vessel. The pre-wet/rinse station is preferably one of the type available from Semitool, Inc. It will now be recognized that a wide variation of processing station configurations may be used in each of the individual processing tools **450**, **455**, and **500** to execute electroless plating and electroplating processes. As such, the foregoing configurations are merely illustrative of the variations that may be used.

Plating Method Using Electroless Plating and Electroplating

According to a method of the present invention, workpieces, such as semiconductors wafers, having first been processed to have a seed layer applied thereon, are electrolessly plated and then electroplated. The method is schematically described in FIG. **50**.

A barrier layer is first applied (step 1) to features on a surface of a workpiece. The barrier layer can be applied by PVD or CVD processes. A seed layer is then applied (step 2) onto the barrier layer. The seed layer is preferably a Cu seed layer applied by a PVD or CVD processes. After the seed layer is applied, the workpiece can be placed in an electroless plating reactor as described below. An electroless plating bath is provided in the reactor and the workpiece is exposed to the plating bath to plate a conductive layer, preferably copper, thereon (step 3). The conductive layer is applied as a blanket to the extent that small and high aspect ratio vias and trenches are filled, but not to the extent that large vias and trenches are completely filled. By terminating the electroless plating at this point, a shorter time period in the overall process can be achieved. The workpiece having the electrolessly plated conductive layer thereon is then removed from the electroless plating reactor and transferred to an electroplating reactor wherein a further conductive layer, preferably copper is applied over the electrolesaly plated conductive layer (step 4). The electroplating process has a higher deposition rate and has adequate filling conformality to fill the larger trenches and vias.

The electroless plating recipe can be a known recipe such as disclosed in the background section of this application in the article by V. M. Dubin, et al., or as describe in U.S. Pat. Nos. 5,500,315; 5,310,580; 5,389,496; or 5,139,818, all incorporated herein by reference. Further, the foregoing processing sequence can be carried out in any of the tools illustrated in FIGS. **47–49**.

Numerous modifications may be made to the foregoing system without departing from the basic teachings thereof. Although the present invention has been described in substantial detail with reference to one or more specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the scope and spirit of the invention as set forth in the appended claims.

What is claimed is:

1. A contact assembly for providing electrical contact between a workpiece and a source of electrical power, the contact assembly comprising:
   - a body member having an inner wall defining an open region sized larger than the workpiece;
   - a contact system having a plurality of cantilevered spring contacts extending at least generally radially inwardly with respect to the inner wall to a location in the open region; and
   - a barrier member having a radially transverse portion projecting inwardly from the body and into the open region, the barrier having a lip radially inwardly from the spring contacts defining a processing aperture sized smaller than the workpiece, wherein the lip is configured to contact the workpiece.

2. A contact assembly as claimed in claim 1 wherein the plurality of contact are in the form of discrete flexure contacts.

3. A contact assembly as claimed in claim 2 wherein the flexure contacts extend radially inward toward the center.

4. A contact assembly as claimed in claim 1 wherein the spring contacts extend inward at an angle with respect to a radius of the processing aperture.

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TITLE: Methods and apparatus for processing the surface of a microelectronic workpiece

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5. A contact assembly as claimed in claim 2 wherein some of the flexure contacts have a greater length than the remaining flexure contacts.

6. A contact assembly as claimed in claim 2 wherein at least some of the plurality of flexure contacts each include an upstanding portion, a transverse portion, a vertical portion, and a wafer contact portion.

7. A contact assembly as claimed in claim 1 wherein the plurality of contacts are adapted for executing a wiping action against the surface of the workpiece as the workpiece is brought into engagement with the contacts.

8. A contact assembly as claimed in claim 1 further comprising a contact support member for captivating at least a portion of the plurality of contacts within a channel defined between the contact support member and the outer body member, the contact support member being disposed radially interior of the outer body member.

9. A contact assembly as claimed in claim 8 wherein the contact support member includes a groove, and the contact assembly further comprises a wedge member disposed to engage said groove along with the discrete flexures to thereby secure the contacts with the contact support member.

10. A contact assembly as claimed in claim 9 wherein at least a portion of the wedge member assists in stiffening the flexing of the contacts as a workpiece is brought into engagement with the contact assembly.

11. A contact assembly as claimed in claim 1 wherein the plurality of contacts are comprised of platinized titanium.

12. A contact assembly as claimed in claim 1 wherein the outer body is comprised of a dielectric material.

13. A contact assembly as claimed in claim 1 wherein the plurality of flexure contacts are integrated with a corresponding common ring.

14. A contact assembly as claimed in claim 1, wherein the contacts are in the form of a Belleville ring contact.

15. A contact assembly as claimed in claim 1 wherein the barrier member comprises a lip formed integrally with the outer body member adapted for engaging the surface of the workpiece.

16. A contact assembly as claimed in claim 1 wherein the barrier member comprises an elastomeric seal member supported by the outer body member, the elastomeric seal member adapted for engaging the surface of the workpiece.

17. The contact assembly of claim 1 wherein the contact system further comprises a conductive ring and the cantilevered spring contacts of the contact system comprise fingers integral with the conductive ring that project radially inwardly along a radius of the open region and upwardly at an acute angle with respect to a plane defined by the open region of the body.

18. The contact assembly of claim 1 wherein the contact system further comprises a conductive ring and the cantilevered spring contacts of the contact system comprise fingers integral with the conductive ring that project generally radially inwardly from the conductive ring at an angle with respect to a radius of the open region and upwardly at an acute angle with respect to a plane defined by the open region of the body.

19. The contact assembly of claim 1 wherein the contact system further comprises a conductive ring and the cantilevered spring contacts of the contact system comprise fingers integral with the conductive ring that project radially inwardly from the conductive ring along a radius of the open region.

20. The contact assembly of claim 1 wherein the cantilevered spring contacts of the contact system comprise individual flexure members attached to the body by a wedge, the flexure members having a cantilevered finger projecting radially inwardly from the body to an interior portion of the open region.

21. A contact assembly for providing electrical contact between a workpiece and a source of electrical power in electroplating applications, the contact assembly comprising:

a conductive mount member having a generally annular shape with an opening sized to receive the workpiece, the mount member being the primary support structure of the contact assembly;

a dielectric outerbody attached to the mount member, the outerbody having a barrier section projecting inwardly with respect to the mount member to an interior lip sized to engage a perimeter portion of the workpiece; and

a plurality of flexing contact members electrically coupled to the mount member, the flexing contact members having a first end at least proximate to the mount member and a second end projecting inwardly from the first end to a location between the interior lip of the outerbody and the mount member, the first end of the contact members defining contact points that engage the workpiece and elastically couple the workpiece to the mount member.

22. A contact assembly for providing electrical contact between a workpiece and a source of electrical power in electroplating applications, the contact assembly comprising:

a primary support structure, the primary support structure being a conductive ring having an outer annular surface, an inner annular surface, a top surface and a bottom surface, the inner annular surface being sized to allow the workpiece to pass through the primary support structure;

an outerbody attached to the primary support structure, the outerbody having an annular barrier section projecting radially inwardly with respect to the inner annular surface of the primary support structure to an interior lip sized to engage a perimeter portion of the workpiece; and

a contact system having a plurality of contact members electrically coupled to the primary support structure, the contact members having a first end at least proximate to the inner annular surface of the primary support structure and a second end defining a contact point to electrically engage the workpiece, the first ends of the contact members being generally stationary relative to the primary support structure and the second ends of the contact members projecting inwardly from the first ends to locations between the interior lip of the outerbody and the inner annular surface.

23. The contact assembly of claim 22 wherein the plurality of contact members comprises individual flexure members spaced apart from one another around the primary support structure, each flexure member having an upstanding portion contacting the support structure and a transverse portion projecting inwardly from the upstanding portion to extend inwardly with respect to the inner annular surface of the primary support member.

24. The contact assembly of claim 22 wherein the contact system further comprises a conductive arcuate member and the contact members comprise a plurality of generally flat fingers projecting inwardly from the conductive arcuate member, the conductive arcuate member being coupled to

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TITLE: Methods and apparatus for processing the surface of a microelectronic workpiece

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the primary support structure so that the fingers extend generally radially inwardly with respect to the inner annular surface of the primary support structure upwardly at an acute angle with respect to a plane defined by the bottom surface of the primary support structure.

25. A contact assembly for providing electrical contact between a workpiece and a source of electrical power, the contact assembly comprising:

a primary support structure having an outer wall, an inner wall, a first surface between the outer wall and the inner wall, and a second surface between the outer wall and the inner wall, wherein the inner wall defines a receiving opening larger than the microelectric workpiece;

a barrier projecting inwardly with respect to the inner wall of the primary support structure to an interior lip configured to engage a perimeter portion of the workpiece, the interior lip of the barrier section defining a processing opening smaller than the microelectronic workpiece; and

a conductive contact system attached to the primary support structure, the contact system having plurality of contact members that have a base end at least proximate to the primary support structure and a contact end projecting inwardly with respect to the inner wall to a location between the interior lip of the outerbody and the inner wall, wherein the contact members flex about the base ends toward the barrier section when the workpiece engages the contact ends and moves through the receiving opening toward the second surface of the primary support member.

26. The contact assembly of claim 25 wherein:

the primary support structure comprises an electrically conductive ring; and

the barrier comprises a dielectric outer body attached to the electrically conductive ring.

27. The contact assembly of claim 25 wherein the contact system further comprises an annular conductive ring having an opening and the contact members comprise a plurality of cantilevered tabs projecting inwardly from the conductive ring toward the opening.

28. The contact assembly of claim 25 wherein the contact system comprises a plurality of individual flexure members such that each flexure member defines a contact member.

29. A contact assembly for providing electrical contact between a workpiece and a source of electrical power in electroplating applications, the contact assembly comprising:

a primary support structure having an inner wall defining an open region sized larger than the workpiece; and

a contact system coupled to the primary support structure, the contact system having a plurality of cantilevered spring contacts extending at least generally radially inwardly with respect to the inner wall to a location in the open region, the cantilevered spring contacts having a pivoting end at least proximate to the primary support structure and a contact end in the open region, wherein the cantilevered spring contacts flex as a workpiece engages the contact ends and moves through the open region causing the contact ends to move laterally across a front surface of the workpiece.

30. The contact assembly of claim 29 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project radially inwardly from the conductive ring along a radius of the open region.

31. The contact assembly of claim 29 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project generally radially inwardly from the conductive ring at an angle with respect to a radius of the open region.

32. The contact assembly of claim 29 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project radially inwardly from the conductive ring along a radius of the open region and upwardly at an acute angle with respect to a plane defined by the open region.

33. The contact assembly of claim 29 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project generally radially inwardly from the conductive ring at an angle with respect to a radius of the open region and upwardly at an acute angle with respect to a plane defined by the open region.

34. The contact assembly of claim 29, further comprising a barrier having a transverse section projecting radially inwardly with respect to the inner wall of the primary support structure to an interior lip radially inward of the contact ends of the contact members, wherein the lip of the barrier is configured to engage a perimeter portion of the workpiece.

35. The contact assembly of claim 34 wherein:

the primary support structure comprises an electrically conductive ring; and

the barrier comprises a flexible dielectric outer-body having a first section attached to the primary support structure and a second section extending transverse to the first section, the second section of the dielectric outer-body defining the transverse section of the barrier.

36. The contact assembly of claim 35 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project radially inwardly from the conductive ring along a radius of the open region.

37. The contact assembly of claim 35 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project generally radially inwardly from the conductive ring at an angle with respect to a radius of the open region.

38. The contact assembly of claim 35 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project radially inwardly from the conductive ring along a radius of the open region and upwardly at an acute angle with respect to a plane defined by the open region.

39. The contact assembly of claim 35 wherein the contact system further comprises a conductive ring, and wherein the pivoting ends of the spring contacts are integral with the conductive ring and the contact ends of the spring contacts project generally radially inwardly from the conductive ring at an angle with respect to a radius of the open region and upwardly at an acute angle with respect to a plane defined by the open region.

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